Stimulus-Independence of Noise Correlations is Beneficial for Short-Term Population Coding in MT

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The noise correlation of orientation selective populations in the middle temporal (MT) area is known to depend on the difference in their preferred directions\textsuperscript{[1,2]}. Here, we construct a multivariate Poisson (MVP) model of spike-counts of an orientation selective population of up to 100 MT neurons in order to compare the impact of different correlation structures on coding at a time scale of tens of milliseconds.

In accordance with experimental findings, the model has the following constraints: (1) We assume von Mises tuning functions with firing rates between 10 Hz and 60 Hz. (2) Covariances are strictly decreasing for increasing differences in preferred directions up to a margin with a specified mean of correlation coefficients. (3) With respect to the number of hidden variables, the model complexity is minimal subject to the first constraints. We find that a MVP model with only pairwise correlations cannot reproduce the mean correlations observed experimentally; on the other hand, the constraints yield a unique higher order system of correlations. Within this model class, near stimulus-independence of the correlation coefficients produces the best fit to the neurophysiological data, i.e. the dependence residue is close to the experimentally observed one.

The model is complemented by a stimulus readout. We assess the mean square error (MSE) of optimal decoders and compare the normalized average Kullback-Leibler divergence ($\Delta I/I$) between the posterior distribution of the true responses and the posterior distribution of independent responses. Since the computation of the Bayes-optimal posterior has exponential complexity, we apply an approximation based on an orthonormal system for the likelihoods. We estimate coding capabilities within 30 ms windows for different models in the class: one with a correlation structure that exhibits stimulus-independent covariances and thus stimulus-dependent correlation coefficients, a model with a structure that shows near stimulus-independent correlation coefficients (the best fitting model), and models with intermediate structures. It is found that the best fitting model is not optimal in terms of the MSE readout performance. However, $\Delta I/I$ turns out to be minimal for the best fitting model. Furthermore, the readout performance of a MT model without any noise correlation is better than the readout performance of any model in the investigated model class. These findings suggest that MT optimizes the correlation structure in the encoding process to let the resulting posterior come near to the posterior of a model with independent noise. Therefore, the findings indicate that MT cannot benefit from noise correlations for short-term coding.

Acknowledgments
This work was supported by BMBF grant 01GQ0410.

References